Swoosh and Boom

QUARTERLY

Indian Head Division

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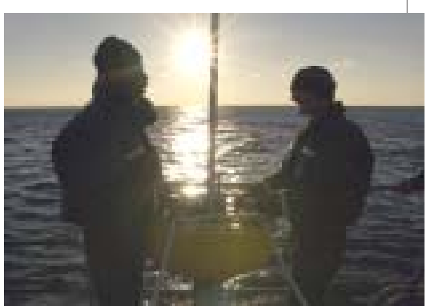
Swoosh and Boom Quarterly



Two USS O'BANNON (DD-987) sailors prepare to deploy the IMPASS System in preparation for a fire exercise early in the morning.

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Indian Head Division
Naval Surface Warfare Center

Captain Joseph N. Giaquinto
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The mission of the Indian Head Division, Naval Surface Warfare Center (IHDIV/NSWC) is clearly and succinctly stated in the Command presentation:

"Rapidly move any 'energetics' product from concept through production, to operational deployment."

Some might suggest that these capabilities can be found at other facilities in Navy, DOD, and even commercial organizations. While it is true that some of them do exist at other places, it is worthwhile to note the specifics that make IHDIV/NSWC **truly unique** in the world of energetics.

As the Navy's technical lead in energetics expertise, IHDIV/NSWC possesses:

- The nexus of intellectual capital for energetics research, development, testing, and evaluation. This team, over 1450 strong, stands out as the largest energetics workforce found in Navy. Almost 900 scientists, engineers, and other technical experts, including 55 holding Ph.D.s, are dedicated to the work of energetics—the largest grouping found in the warfare centers.
- Full-spectrum hands-on capacity, from cradle to grave for basic research, applied research, technology demo, prototyping, engineering development, acquisition, production, in-service engineering/mishaps/failure investigations, surveillance, and energetics material demil technology research and development.
- Expertise and capacity for underwater warheads and explosives.
- Expertise and capacity for **all** categories of energetic materials: gun propellant, rocket and missile propellant, primary explosives, booster explosives, main charge explosives for **all** applications (underwater, air-launched, surface-launched, urban ops, special ops, anti-terrorism), reactive materials, and specialty chemicals.
- Expertise and capacity for the following energetic systems: air surface warheads, underwater warheads, rocket/missile motors, gun projectiles and propulsion, mines and mine countermeasures, fuzes/ignitors/detonators, and cartridge-actuated devices and propellant-actuated devices.
- Expertise and capacity from laboratory to full-scale manufacturing of **all** types of energetics including melt-cast, pressed, cast, extruded, injection molded, and co-layered/gradient.

In addition, IHDIV/NSWC handles the largest energetics workload in the Navy, accounting for 60 percent of all Navy explosives, propellants, pyrotechnics, reactive materials, related chemicals and fuels, and associated ordnance products. IHDIV/NSWC has developed 13 Navy-qualified explosives, transitioned into 47 Navy, Army, Air Force, and Marine Corps weapons. Even more unique is that over 70 percent of new explosives deployed in U.S. weapons since 1985 were developed by IHDIV/NSWC. This success is largely due to IHDIV/NSWC's ability to design for production, reliability, and maintenance.

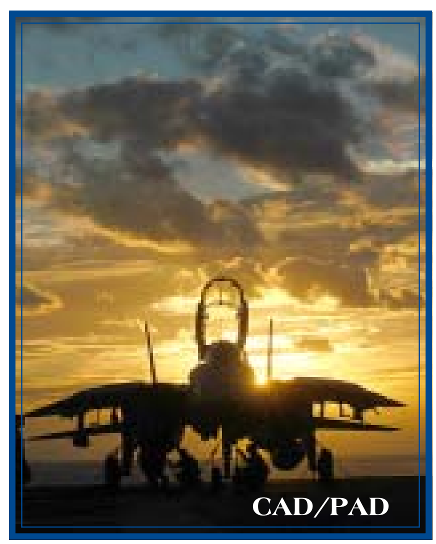
This translates into IHDIV/NSWC possessing the most synergistic energetics system engineering capabilities in existence, resulting in quick response in wartime and rapid transformation of technological breakthroughs. The IHDIV/NSWC workforce is versed in all phases of the energetics lifecycle–our folks know and understand the big picture, the technical intricacies and complexities of the energetics process, and how each phase/part contributes to and impacts the whole.

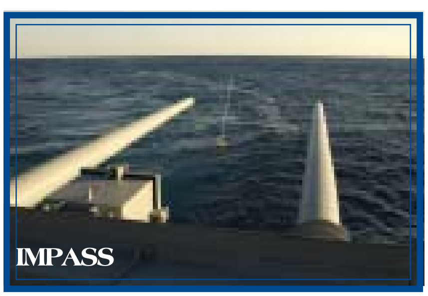
I like to think of energetic materials as the most fundamental component in America's power projection capabilities, and that makes IHDIV/NSWC extremely unique and extremely valuable to our Nation. Most folks may not know where Indian Head, MD is, but IHDIV/NSWC keeps the very tip of America's warfighting spear razor sharp.

This Spring edition of the Swoosh and Boom is our continued testament to the exceptional work performed at the Indian Head Division, Naval Surface Warfare Center. We are extremely proud of these most recent accomplishments, and of our very unique and critical role within the Navy.

We ensure operational readiness of the United States and allied forces by providing technical capabilities necessary to rapidly move any "energetics" product from concept through production, to operational deployment. Our capabilities include: research, development, testing, and engineering; acquisition; manufacturing technology; manufacturing; industrial base, fleet, and operational support for warheads; explosives; propellants; pyrotechnics; energetic chemicals; rocket, missile, and gun propulsion systems; missile simulators, trainers, and test and diagnostic equipment; tri-service cartridge-actuated devices, propellant-actuated devices, and aircrew escape propulsion systems; and other ordnance products.

Our capabilities provide technical expertise for special weapons, explosive safety, and ordnance environmental support. These technical capabilities and this expertise support all Naval warfare areas as well as the Army, Air Force, and private sector.





Proof of Concept: Lean "Cells" Produce Better-Than-Expected Manufacturing Efficiencies

by Allie Buzzell
Adeptus Associates

The Indian Head Division, Naval Surface Warfare Center (IHDIV/NSWC) is known as a pioneer in converting from batch processing to continuous processing of energetic materials. A parallel and equally significant development is IHDIV/NSWC's groundbreaking application of lean manufacturing principles to convert from batch assembly to single piece flow in energetics manufacturing.

In September 2004, the CAD Lean Manufacturing Team within the CAD/PAD Manufacturing Division successfully demonstrated for the first time that lean manufacturing concepts yield remarkable labor efficiencies in the production of cartridge-actuated devices (CADs). These concepts produce the potential for significant cost savings, while maintaining or elevating the level of safety and quality of the product.

By the end of 2004, completion of a similar demonstration by the Cartridge Lean Manufacturing Team is expected to show that lean concepts will also bring cost-saving labor and motion efficiencies to the fabrication of cartridges.

Lean manufacturing is a set of principles that improve the manufacturing process, making it more efficient and less expensive by producing a higher quality product in less time. Lean concepts have been used in the automobile industry and other manufacturing settings for years, but have never been applied in a military production environment where operators handle energetic materials as part of the fabrication process.

The initial groundwork for the CAD/PAD lean cell demonstrations was a study by the Center for Energetic Concepts Development (CECD), a cooperative program between IHDIV/NSWC and the University of Maryland's Mechanical Engineering Department. A team led by Professor Jeffrey Herrmann studied the application of lean manufacturing principles to the fabrication of the M21 cutter, a CAD used to release cargo from aircraft.

Many of the concepts addressed in the CECD study were later incorporated into the two demonstration projects within the CAD/PAD Manufacturing Division. According to Director Darrin Krivitsky, both demonstrations involve manufacturing two product lots in a lean "cell."

A lean cell is a collection of workstations that physically tie together in a single location all the equipment, materials, and tools used in the fabrication process of a given item. Rather than assembling a complete unit, each operator working in the cell instead performs one or a series of discrete steps in the assembly process. As each step or series is completed, the unit is passed from one operator to the next until all the components have been assembled.

The CAD Lean Manufacturing Team demonstration involved the assembly of one lot of 436 M25A1 thrusters, devices that use explosives to eject the canopy off the T-38 training aircraft in an emergency. The assembly of CADs for

Employees working at the lean cell. The operators report the cell is comfortable, promotes interaction, improves morale, and inhibits fatigue.

aircrew escape systems, and other uses, requires experienced operators and the highest commitment to quality control.

In fact, the lives of our warfighters depend on the fail-safe functioning of the devices, according to Nick Scalfaro, manager of the CAD/PAD Manufacturing Branch. It is imperative in the lean cell demonstrations to maintain, or even improve, the safety of the manufacturing process and the quality of the product being produced.

For the CAD Lean Manufacturing Team demonstration, Project Engineer Steve Possehl designed the lean cell from both off-the-shelf and custom components. The cell is just 15 feet long—extremely small by traditional manufacturing standards. “What we do in a large, functionally-organized manufacturing bay can be done in a much smaller space designed to handle the entire assembly process,” said Possehl.

The cell design is based on sound ergonomic principles, with the operators sitting side-by-side, close enough to hand a unit to the next operator without leaning or overreaching. A bright overhead light provides excellent illumination to prevent eyestrain. The operators report that the lean cell is comfortable, promotes interaction, improves morale, and inhibits fatigue.

The cell accommodates three operators seated at assembly stations, and two or three other operators handling other tasks, including hardware and materials supply, x-ray inspection, packaging, labeling, and cleanup.

Each operator is proficient in all of the tasks performed in the cell, so that when someone takes a break or is absent, the work continues uninterrupted.

The CAD Lean Manufacturing Team (from left to right): Kathleen (Kitty) Hart, Steve Possehl, Frances Makle, Sadie Cobey, Christine Butler, Ester Adams.

One of the principal goals of the lean cell concept is to reduce the unnecessary movement of materials. In a lean configuration, everything required for assembly is either built into the cell or moved there prior to the start of production.

Conversely, in the traditional manufacturing configuration, materials and components must be moved to the equipment, sometimes traveling hundreds of feet multiple times within a manufacturing bay, or from building to building.

Set-up and cleanup times are reduced, making it possible to convert the production line to begin fabrication of a new item in just one hour. The space utilization principles underlying the cell design also allow operators to find a tool in one minute or less, thus expediting the setup process.

The CAD lean manufacturing cell demonstration showed that potential savings in time, motion, and labor are much greater than anticipated. The lean cell reduced the time it takes to manufacture the CAD product from 1,000 hours in six weeks to 550 hours in six days, representing a 46 percent reduction in labor. The goal for the demonstration was a 15 percent labor reduction.

The CAD Lean Manufacturing Team has processed two lots on the manufacturing line to date. The M25A1 thruster program and the M53 initiator program, both Air Force programs, have utilized the lean cell manufacturing line. Initial results from the M25A1 thruster and M53 initiator efforts have led to 49 and 20 percent cost savings, respectively, totaling approximately $53,000 in savings.

The attendant cost savings will emerge later, after the CAD/PAD Manufacturing Division reinvests and retools to convert other programs to lean cells. According to Krivitsky, before the end of fiscal year 2005, the CAD/PAD Manufacturing Division plans to transition 80 percent of its cartridge and cartridge-actuated products from the batch manufacturing process to lean cells.

According to Scalfaro, these developments will make IHDIV/NSWC's CAD/PAD manufacturing capabilities more price-competitive, allowing the division to bring in more work, and ultimately to introduce greater levels of safety and reliability to the products on which our warfighters depend.

IMPASS Provides Naval Gun Range on the Open Ocean

by Allie Buzzell
Adeptus Associates

When it became clear that the Navy would have to abandon its bombing range on Vieques Island, Puerto Rico, engineers at Indian Head Division, Naval Surface Warfare Center (IHDIV/NSWC) already had a new concept ready to roll out, thanks to visionary "blue-skying" years earlier and a small technology fund that got the ball rolling.

The Atlantic Fleet has long used the Atlantic Fleet Weapons Training Facility (AFWTF) at Vieques Island for both live-fire unit training and combined exercises to maintain combat readiness.

IMPASS team instructing USS O'BANNON sailors on sensor buoy assembly procedures prior to deploying system into the sea.

But on 19 April 1999, a training accident at the facility took a civilian's life and fueled a movement among island residents to halt Navy training exercises, which had been ongoing for almost 60 years. The loss of AFWTF meant that suitable alternatives had to be found.

The Navy carefully studied its options for maintaining the Atlantic Fleet's combat readiness and found a possible solution with the Integrated Maritime Portable Acoustic Scoring and Simulator (IMPASS) system, which IHDIV/NSWC engineers had begun to develop two years earlier.

In 1997, several gun propellant engineers were sitting around a conference table, "blue-skying" about the possibility of using acoustic sensing technology to recognize a high-explosive 5-inch round when it hits the water. The idea was to see whether it was possible to pinpoint exactly where Navy gun crews "punched holes in the water" after firing into the open ocean.

Through a small technology fund administered by IHDIV/NSWC, and later through funding from the Office of the Secretary of Defense Live Fire Test and Training Group, the group of engineers had developed a virtual, open-ocean alternative to land-based bombing ranges.

IMPASS team and USS O'BANNON crew picking up the buoys in a Rigid Hull Inflatable Boat (RHIB) at the end of the day.

Their IMPASS system concept is a low-cost, waterborne acoustic impact scoring system and simulator that lessens the Fleet's dependence on bombing ranges by allowing ships to conduct combat readiness training in the open ocean.

IMPASS can transform an open-ocean area into a range suitable for live-fire exercises and supplementary training at sea for Navy and Marine Corps sea-air-ground combat units.

After a series of prototype demonstrations and field trials, engineers at IHDIV/NSWC delivered three IMPASS units to the Navy Fleet—two in December 2002 and one in January 2003. The Navy evaluated the systems from an operational and training standpoint, with IHDIV/NSWC engineers providing support both shipboard and ashore.

The IMPASS system works using existing sensor, signal processing, and computer and telecommunications technology to accurately locate a high-energy impact on water by detecting the resultant sound energy. The technology is based on the detectable sound a projectile generates when it hits water. In other words, the ordnance creates an acoustic event when fired, which can be detected by sensor buoys and accurately located using a global positioning satellite (GPS). The resulting data are transmitted to a computer aboard ship for further processing, visual representation, and feedback.

An IMPASS unit's acoustic sensors are built into seven buoys. Five of the buoys are deployed in a pentagon shape in the water, the sixth records the ship's position, and the seventh is a spare. Acting together, these buoys triangulate the location of any impact within 50 meters in relation to the actual fall-of-shot.

The buoys' signal-processing circuits receive data and detect that an acoustic event has occurred, while GPS continuously monitors the buoys' location. The radio frequency repeater system permits data transmission between the buoys and system controller.

The buoys' signal processing software, with its embedded algorithms, is the technological heart of the IMPASS system. Among other things, it performs periodic built-in test functions to monitor the normal functioning of the components. locations and times to triangulate and

One of five IMPASS sensor buoys deployed and ready to record and transmit high explosive impact events.

Sailors aboard the USS O'BANNON standby ready to assist with the IMPASS system deployment.

A portable, PC-based computer onboard the ship receives and processes data to determine the actual and relative positions of acoustic events caused by the projectiles' impact in the water. The controller is capable of functioning as a stand-alone simulator, or operating in conjunction with the buoys as an acoustic scoring system. In the latter mode, the system controller calculates impact events relative to the GPS position of the firing platform and provides nearly real-time feedback to the crew. The controller also monitors and displays the operational status of the sensors and the main system.

For training purposes, the software can superimpose a virtual landmass in the target area and display it graphically on the system controller screen. This enables the ship's crew or spotter to assign and fire upon targets and to adjust spots as necessary, creating an extremely realistic virtual Naval Surface Fire Support (NSFS) range for ships in the open ocean.

Currently, IMPASS provides a two-dimensional picture of a virtual topography. The presentation correlates with a defined area over the open ocean. Once the ship reaches the appropriate distance away from the buoy field, it engages and shoots at the virtual target. Future IMPASS systems will be able to display a full three-dimensional representation of topography that corresponds to an actual land mass.

In engaging the target, the gun operator fires at the simulated view of an object or location he might see in combat, but the ordnance actually lands in the water within the array of buoys. The buoys sense the acoustic characteristics of the impact and send a signal back to "score a hit" to the system controller, which monitors the target practice. The system controller uses GPS locations and times to triangulate and display the impact locations of the round. The system controller can be located either aboard the ship, onshore, or both.

For their vision and technical efforts in developing and demonstrating the IMPASS system, the joint IHDIV/NSWC and Dahlgren Division team was awarded the IHDIV/NSWC 2001 Roger M. Smith Team Award. Through two years of development work and field trials, the IMPASS team made a significant contribution to force readiness and the safety and performance of future U.S. warfighters.

In IMPASS, the Navy had found a viable alternative not only for AFWTF, but also for land-based bombing ranges in general. In April 2003, the USS *Thorn* completed the first NSFS qualification using the IMPASS system.

The success of the IMPASS concept can be partially attributed to the team's focus on the Fleet customer, which characterized the entire development effort. From the early stages of the process, the team sought the input of the Naval officers who might one day use the system. Rather than asking the Fleet to adapt to systems or gadgets that were invented, the engineers wanted input from the Fleet to shape the concept as the technology was being developed.

USS O'BANNON Mk 45 inch bow gun recently fired during a fire exercise. Spent cartridges from recently fired rounds lie on the deck.

The IMPASS technology, although originally designed to support live-fire training, also has applications to weapons testing. Accordingly, a new project will use the IMPASS technology to bridge the U.S. military's testing and training requirements. The Joint Distributed Integrated Test and Training System project will explore the feasibility of an end-to-end weapons testing and training system.

Although the IMPASS system does not completely replace the superior training afforded at land-based bombing ranges, it has many unique advantages. Most significantly, ships can take their live firing ranges with them wherever they go. The IMPASS components are lightweight, compact, and easily stored aboard ship. As a result, the Fleet is not anchored to a particular location for exercises, and its ability to conduct training and qualification exercises no longer depends on the availability or proximity of a fixed, instrumented range.

The Office of Naval Research recently designated IMPASS as the principle component in its new Virtual At-Sea Training (VAST) system.

With the additional funding and support available through the VAST program, new applications of the IMPASS concept are also being discussed. One option under investigation involves expanding the existing Indoor Simulated Marksmanship Trainer (ISMT) systems currently in use by the Marine Corps. Such an enhanced system would include an interactive video-based simulator and a computer-based controller that would provide links between the IMPASS and ISMT systems, as well as among exercise participants. Forward observers and air/sea units could then operate from the same virtual map, even though they are in different locations.

The IMPASS/VAST system's portability, lowered risk, and environmental sensitivity have had a positive impact on combat readiness and generated substantial operating and support cost savings. When the Fleet's combat readiness—and the nation's security—was threatened by the loss of an essential training asset, the ingenuity of those engineers had already found a virtual alternative to land-based bombing ranges.

The original IMPASS team has evolved into a full-fledged NAVSEA integrated product team to further develop the IMPASS concept. The NAVSEA team, sponsored by PMA-248, combines IHDIV/NSWC personnel with scientists and engineers at Naval Undersea Warfare Center (NUWC) Newport, RI; NSWC Dahlgren Division, VA; and the Coastal Systems Station (CSS), FL.

NUWC Newport's expertise in acoustics and experience evaluating underwater firing ranges, together with NSWC Dahlgren Division's work in systems and gun integration, and CSS's modeling and visualization tools, will enable further development of the IMPASS system. Through these partnerships, new technologies are being incorporated into IMPASS to give it even greater utility to the Fleet in the areas of training, qualification, and combat readiness.

Venom Penetrator Chemical Mine Neutralization

by Scott Wacker
Weapons Department

A mine countermeasure technology, designed to neutralize anti-tank and anti-invasion mines in beach and surf zones, is currently under development at the Indian Head Division, Naval Surface Warfare Center (IHDIV/NSWC).

This new system, rightly named the Venom Penetrator, can be launched via air or surface gun over a minefield, penetrating various overburdens (air, water, and sand) and mine case materials.

The primary function of the Venom Penetrator is to achieve complete consumption of the explosive fill, resulting in a complete neutralization of the mine. Once the penetrator perforates the mine case, it breaks up the explosive fill causing a highly exothermic destruction of the mine and consumption of the explosive fill.

The Office of Naval Research is sponsoring the Venom Penetrator Countermine Demonstration Project as part of the Far Term Assault Breaching System solution. IHDIV/NSWC has teamed with two prime contractors, Science Applications International Corporation (SAIC) and Boeing, to demonstrate two surf/beach zone mine clearing systems.

IHDIV/NSWC will develop a chemical penetrator to demonstrate mine neutral-

The guided missile destroyer USS WINSTON S. CHURCHILL fires its Mk 45 Mod 4 5-in/62-cal, lightweight gun mount during an exercise in the Atlantic Ocean. The SAIC system will use the 5-inch gun to deliver the chemical penetrator developed in the Venom Penetrator Countermine Demonstration Project.

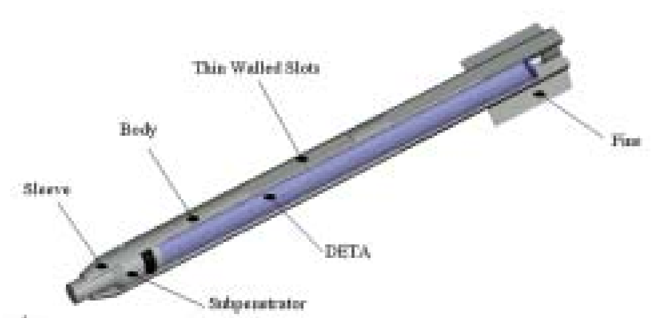
Aviation Ordnanceman aboard USS JOHN C. STENNIS prepare a 2,000-lb BLU-109 penetrating bomb modified as a GBU-31 Joint Direct Attack Munition (JDAM) in a weapons magazine. The JDAM is a guidance kit that converts existing unguided bombs into precision-guided "smart" munitions. Under this program, the Boeing system will deliver the penetrator payload using JDAM Guided Munitions airframe.

ization in the surf/beach zones.

The SAIC system will deliver this payload using 5-in and 155-mm naval guns, while the Boeing system will deliver the payload using the Joint Direct Attack Munition (JDAM) Guided Munitions airframe. The objective of this research is to create a prototype penetrator design that has the capability to survive launch loads, achieve stable flight, traverse multiple overburdens, penetrate various mine case materials, damage the explosive fill, deposit the reactive chemical, and achieve full consumption of the energetic fill (less than 0.5 lb remaining).

At the conclusion of the program, a final demonstration against beach zone targets in the proud (surface) and buried (6-in dry sand) configurations, as well as against surf zone targets in the submerged (3-, 7-, and 8-ft water) and buried submerged (3-ft water and 6-in wet sand) configurations must be completed.

The first stages of the project were focused on examining the relationship between the rubble zone and fluid quantity required to ignite the explosive fill. A test series was set up using different penetrator masses, impact velocities, and nose shapes to study the effect of each variable on damage creation. The results of the test series were utilized in the design of the subpenetrator and in the sizing of the fluid flow slots on the penetrator.



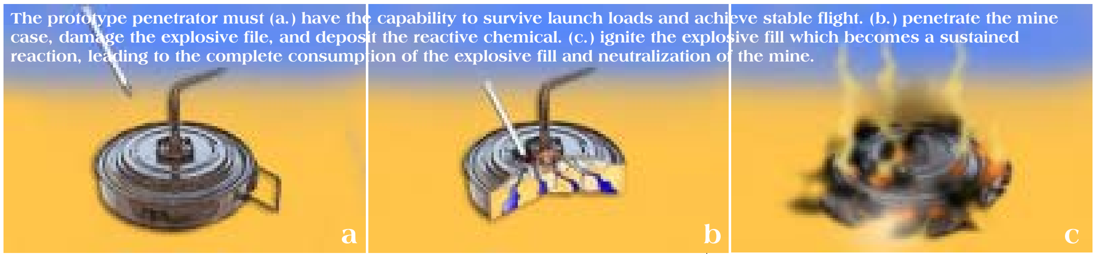
Baseline Penetrator Component Description

A notional penetrator design was defined by system trade studies and terminal ballistics requirements using analytical tools. After the concept was defined, analytical tools such as ABAQUS, CTH, and PATRAN were used to refine the design.

Another tool, VENPEN, was developed as a semi-empirical FORTRAN analysis tool (replicated in Quattro Pro) derived from the IHDIV/NSWC terminal ballistics suites. The program can accept user-defined parameters such as dart mass, diameter, velocity, trajectory, target material, target thickness, target layering, and overburdens. The output parameters of the program include residual velocity, depth of penetration, deceleration, time profiles, fluid flow velocity, and accumulative fluid flow.

The baseline prototype penetrator consists of a three-finned tubular body with two thin-walled, machined slots. The front of the penetrator consists of a deformable sleeve and a subpenetrator with an attached O-ring. The surface contact chemical is loaded through the back of the penetrator body, where a Teflon ball and setscrew are used to seal the penetrator.

Upon dispense from the round, the penetrators must first survive the setback loads, and then must stabilize to ± 5 degrees prior to first overburden impact. Analysis and testing were completed to determine the appropriate dispense altitude, velocity, and angle of attack, as well as structural, drag, damping, and center of gravity requirements for the penetrator.



The prototype penetrator must (a.) have the capability to survive launch loads and achieve stable flight. (b.) penetrate the mine case, damage the explosive file, and deposit the reactive chemical. (c.) ignite the explosive fill which becomes a sustained reaction, leading to the complete consumption of the explosive fill and neutralization of the mine.

Functional Requirements of Penetrator to Achieve Mine Lethality

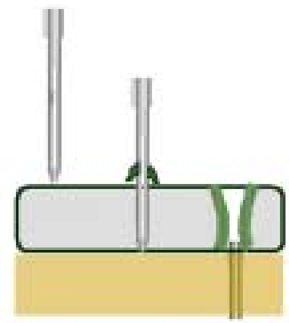
The front end of the penetrator was designed with overburden penetration in mind. The 50 percent blunt subpenetrator creates a cavity in both water and wet sand, in which the entire penetrator rides. In dry sand penetration, the subpenetrator does not create a full cavity around the penetrator. Instead, dry sand penetration results in a deformation of the front-end sleeve and separation of the subpenetrator from the body. Then, under its own momentum, the surface contact chemical continues behind the subpenetrator and into the mine.

Mine cases vary in both material and geometry. Materials can range from thin plastic to thick metal, and the geometry of the cases can include flat, angled, oblique, and layered surfaces. To account for the range of materials and shapes, analytical tools including ABAQUS and VENPEN were used to analyze mine case penetration scenarios. Testing has successfully demonstrated the effectiveness of these tools in predicting penetration of mine cases.

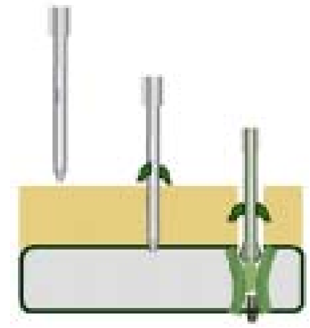
Once the penetrator perforates the mine case, the subpenetrator breaks up the explosive fill, creating a zone of smaller particles within the mine. This zone results in a highly localized surface area, which ignites upon contact with the surface contact chemical.

A major aspect of the penetrator's functionality is the transfer of the surface contact chemical into the explosive fill of the mine. The mode of chemical transfer varies depending on the configuration of the mine.

Upon impact with a surface mine case, the hydrostatic pressure generated by the deceleration of the penetrator ruptures the thin-walled slots along the body of the penetrator. The surface contact chemical is then free to flow into the explosive fill under its own momentum.



Penetrator Functionality Against Surface Mines



Penetrator Functionality Against Buried Mines

Surface contact chemical transfer differs against buried mines. The sand deforms the sleeve creating drag on the body, which allows the subpenetrator and body to separate. A slug of surface contact chemical then follows the subpenetrator into the explosive fill of the mine.

The rubblized explosive fill is instantly ignited when contacted by the surface contact chemical. This ignition then transfers to the bulk charge of explosive where it becomes a more sustained reaction, leading to the complete consumption of the explosive fill.

There are numerous benefits to this technology. The penetrator has a simple and low-cost mechanical design, does not require fuzing, does not pose an unexploded ordnance threat to troops or vehicles, and provides limited visual and infrared lane marking (burning mines). Efforts are continuing in the areas of penetrator performance, as well as understanding and improving the chemical performance against numerous explosive fills.

IHDIV/NSWC Demonstrates Perchlorate Bioremediation of Groundwater

by Randy Cramer
Applied Technology Department

The Applied Technology Department at the Indian Head Division, Naval Surface Warfare Center (IHDIV/NSWC) and Shaw Environmental, Inc. recently demonstrated the use of in situ perchlorate bioremediation technology as an effective means of remediating perchlorate-contaminated groundwater.

Used as an oxidizer in propellants and pyrotechnics, ammonium perchlorate has been detected as a wide-spread groundwater contaminant throughout the country. The health effects and toxicity of perchlorate have been the subject of considerable debate, and recently the National Research Council released a review of human health data that recommended a reference dose of 0.0007 mg/kg per day.

New low-cost remediation technologies will be in demand as both state and federal regulators consider setting parts per billion clean-up and drinking water standards.

This is the demonstration site at Building 1419 at IHDIV/NSWC. The site was found to have parts per million levels of perchlorate and perchlorate-degrading microorganisms.

Ammonium perchlorate is very stable and can persist in the environment for many decades. The stability of perchlorate towards most reducing agents makes the development of remediation technologies difficult. However, specific types of bacteria, when provided a suitable substrate (lactate, acetate, hydrogen gas) are known to metabolize perchlorate during growth, reducing it completely to chloride ion and oxygen. Biological treatment technologies using these naturally-occurring microbes provide an efficient, low-cost process for remediation of contaminated ground-water.

Groundwater and soil samples from a site at IHDIV/NSWC, where past solid propellant wash out activities may have impacted groundwater, were analyzed for ammonium perchlorate. Not only were minute parts of perchlorate detected, but naturally-occurring, perchlorate-degrading microorganisms were also found to be living in the soil.

The bioremediation process occurs when the microorganisms are fed–they reduce the levels of perchlorate in the groundwater as part of their natural growth process.

This is achieved by creating a recirculation cell where groundwater is extracted, mixed with both a lactate feedstock and a neutralizing buffer,

Employees and contractors from Code 20 set up the demonstration equipment.

and injected back into the ground, creating a bioactive zone.

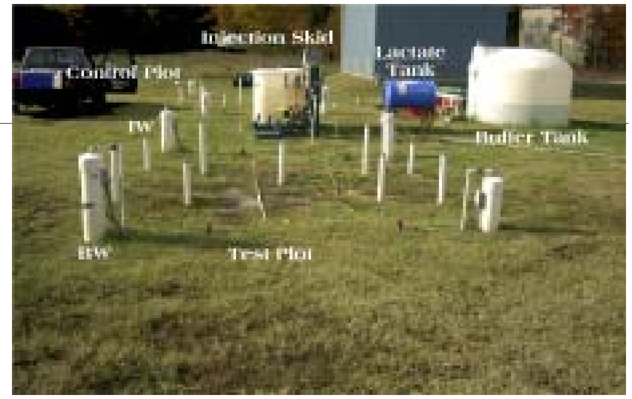
Prior groundwater analysis, based on 17 geoprobe samples, determined the location, dimensions, and number of wells needed for the final design and construction of the demonstration. The control plot and the experimental plot each featured an injection skid, two injection wells, two extraction wells, and five sets of monitoring wells.

An inexpensive set of pumps circulated 20,000 gallons of groundwater through each plot during the course of the 140-day demonstration. The tanks could hold 450 gallons of groundwater for mixing with the lactate feedstock and carbonate buffer before injection.

Before the demonstration began, the perchlorate levels in the test plot averaged 171 mg/L. After the treatment, perchlorate levels were all below 10 mg/L. Two of the wells were below 5 mg/L and three wells were below 1 mg/L after the treatment. The overall reduction of perchlorate exceeded 95 percent within 5 months.

The average perchlorate level of the control plot at the start of the demonstration was 127 mg/L. After the 140 days, the average perchlorate levels were 118 mg/L. In other words, there was no significant change in the perchlorate levels of the control plot where the same amount of water was circulated but without the feedstock.

A full report contains the measurements of pH, alkalinity, concentrations of lactate and perchlorate, as well as nitrate and sulfate, and a discussion of the overall results of this remediation process.



Prior groundwater analysis of 17 geoprobe samples provided the specifications for the final design and construction of the test demonstration seen here. The control plot and the test plot are located side by side.

This study represents one of the first successful field demonstrations of in situ perchlorate bioremediation in a groundwater aquifer, and is the first field test conducted on the East Coast of the United States. This demonstration is also the first trial performed in an acidic aquifer.

The in situ bioremediation equipment is inexpensive and easy to install, and the process is efficient, as perchlorate levels drop off quickly over a short period of time. These results suggest that in the future, in situ perchlorate bioremediation will be a successful approach for treatment of perchlorate in aquifers containing high, localized concentrations of the oxidant.

These tanks hold 450 gallons of the groundwater for mixing with the lactate feedstock and carbonate buffer. Inset: injections skids and control panel.

Respected Explosive Chemists Collaborate at Workshop Co-Hosted by IHDIV/NSWC

by Valerie Olsson
Applied Technology Department

On 2-3 November 2004, the Indian Head Division, Naval Surface Warfare Center (IHDIV/NSWC) and Pacific Scientific, Inc. co-hosted the first primary explosives workshop in Chandler, AZ. The workshop gathered some of the most respected explosive chemists in the nation to collaborate on finding replacements for lead azide and lead styphnate—compounds that require the use of toxic and carcino-genic materials. The lead replacement effort was initiated to comply with NAVSEA Instruction 8020.3 and Executive Order 12856, which limit and restrict the use of lead compounds.

Attendees of the workshop included representatives from IHDIV/NSWC; Pacific Scientific Energetic Materials Company; Energetic Materials Technology; US Army Armament Research, Development and Engineering Center; Wayne State University; Geo-Centers, Inc.; Lawrence Livermore National Laboratory, Los Alamos National Laboratory, Naval Air Warfare Center Weapons Division; and SRI International. This group of scientists represented academia, the national laboratories, private industry, and government agencies. The group included mostly research scientists, analytical chemists, product designers, and test engineers. Having such a broad range of attendees, covering the entire product development process, greatly enhanced the discussions during the workshop.

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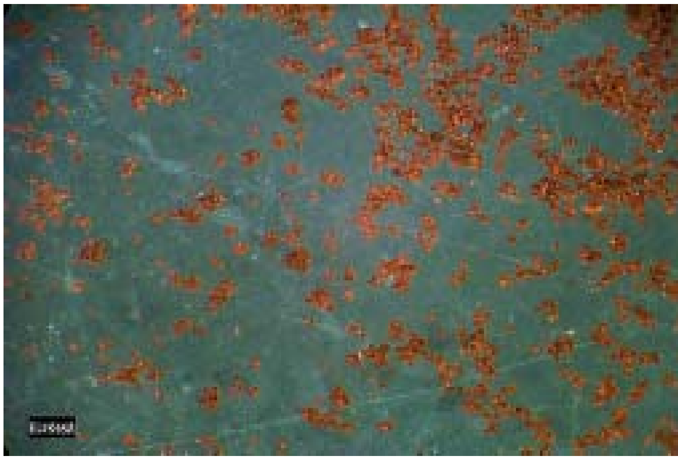
Back row l to r: Dr. Jeff Bottaro, Mr. Magdy Bichay, Dr. Chuck Winter, Dr. Bill Sanborn, Mr. John Fronabarger, Dr. Mike Hiskey, Dr. Robert D. Chapman, Dr. Al Stern. Front row l to r: Mr. Gartung Cheng, Mr. John Hirlinger, Dr. Philip Pagoria, Mrs. Valerie Olsson, Dr. Farhad Forohar, Dr. Peter Ostrowski, Mr. Kelly Armstrong, Dr. My Hang V. Huynh, Mr. Michael Sitzmann.

Sodium 4,6-dinitro-7-hydroxybenzofuroxan (right) and potassium 4,6-dinitro-7-hydroxybenzofuroxan (below) are two of the three lead styphnate replacement compounds being considered.



This workshop focused on research efforts for the replacement of lead azide, as well as testing methodology and results for both lead azide and lead styphnate. Attendees briefed the group on recent developments in their specialties, such as new compounds, synthesis methods, and testing apparatus.

In addition to scientific discussion, the group addressed future funding issues and recommended a joint proposal to leverage funding from the Strategic Environmental Research and Development (SERDP) program, and to develop a briefing for the fuse community to obtain additional funding. The replacement efforts, ongoing since the late 1990s, are primarily funded by PMA 201 and Ogden Air Logistics Center/WMJ, Hill Air Force Base. During the past two years, the SERDP program initiated a seed effort to leverage the program funds.

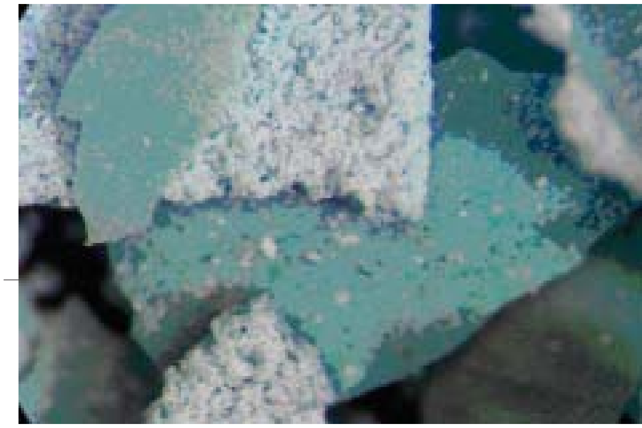
The main objective of the current program is to find drop-in replacements for lead azide and lead styphnate that could be used in cartridge-actuated devices and propellant-actuated devices. The lead azide and lead styphnate combination is widely used in detonators as transfer charges and ignition charges, respectively. These materials are also used in ordnance as priming mixtures for propellants, and as detonators for secondary explosives. The Army requires over 1000 lb per year of lead azide alone for various uses. Lead styphnate is used in even greater quantities as a primer material in military and commercial small caliber ammunition.

These lead-based compounds exhibit excellent performance, but they also release toxic heavy metals into the environment during use and disposal. Since the Environmental Protection Agency has imposed very strict limits for lead discharge, there are no lead azide manufacturers in the United States. Lead styphnate is also not commercially available. Of further concern, the stockpiled lead azide is exhibiting a particle growth issue, which increases its handling sensitivity and renders it unusable.

The replacement effort resulted in the evaluation of approximately 100 potential compounds. Synthesis methods were developed for the most promising replacement candidates. The synthesized compounds underwent a series of initial tests to determine the handling and safety characteristics of the compounds and their detonation properties. Compounds that met the requirements were selected for further evaluation.

After the initial screening phase, 24 compounds were initially synthesized and evaluated: 12 for lead azide and 12 for lead styphnate.

After successful synthesis, these compounds were subjected to a series of screening tests to compare their performance to lead azide and lead styphnate. Based on the screening test results, three lead styphnate replacement compounds and two lead azide replacement



Copper (II) 5-nitrotetrazole (left) and 1,5-Diaminotetrazole, Fe (II) perchlorate complex (below) are the two compounds being considered as replacements for lead azide.

compounds were selected for further evaluation.

The lead azide compounds that exhibited promising results are copper (II) 5-nitrotetrazole, and 1,5-diaminotetrazole, Fe (II) perchlorate complex. Even though the test results were promising, these compounds need further development to improve their particle morphology, to find another oxidizing group instead of perchlorate, and to enhance the crystallization of the copper (II) 5-nitrotetrazole. These improvements hinge on the availability of future funding.

In a separate effort funded by the SERDP program office, the Initiation Systems Development Branch at IHDIV/NSWC tested two lead azide replacement compounds: diaminotetrazole, iron (II) perchlorate (DFeP), and a reduced handling sensitivity silver azide synthesized to reduce its sensitivity to a level more comparable to that of lead azide. The DFeP testing consisted of hot-wire ignition, priming ability tests, and M59 stab detonator loading and functioning. Silver azide was only loaded and functioned in the M59 stab detonator.

As expected, silver azide performed very well in the detonator, though there are reported compatibility concerns with the NOL 130 stab-initiating mix. The performance of the DFeP was acceptable in the hot-wire ignition tests, but marginal in the priming ability tests and in the M59. With further work on the compound, its performance could improve.

The selected lead styphnate compounds are iron (II) 5-nitrotetrazole, sodium 4,6-dinitro-7-hydroxybenzofuroxan, and potassium 4,6-dinitro-7-hydroxybenzofuroxan. Larger batches of these compounds were synthesized and sent to IHDIV/NSWC for chemical analysis and performance testing. The results are being analyzed and compared to lead styphnate performance. This phase will be completed by the end of March 2005. The selected compounds will undergo a design feasibility test (DFT), which determines the performance characteristics of the replacement candidates. A design verification test (DVT) series will be conducted to determine the effects of environmental conditions on performance of the replacement compound.

Upon successful completion of the DVT phase, the replacement compound will undergo tests and procedures required for qualification of primary explosives. The lead styphnate compounds will complete the final stages of the DFT and DVT testing this fiscal year. The goal is to have all tests needed to support the decision for choosing a compound and proceeding into qualification completed by early 2006.

Based on the attendees' feedback, this workshop was very successful and participants made a commitment to support and attend future workshops. IHDIV/NSWC recognizes the usefulness and success of this endeavor and will continue to co-host future workshops.

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